An Analysis Procedure for Advanced Propulsor Design

by

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Abstract

A propeller which operates in the shear flow found near the aft end of marine vehicles experiences an intimate coupling between the propeller's induced velocity field and the rotational inflow. The presence of the propeller's induced velocity field causes the inflow to accelerate, which redistributes the vorticity present in the inflow. This redistribution causes a change in the nominal propeller inflow. Because the propeller now experiences a different inflow, the propeller induced velocity field is altered. Thus, there is an intimate coupling between the vorticity present in the fluid inflow and the propeller-generated induced velocity field.

Lifting surface propeller blade design codes are incapable of analytically representing the vortical interaction between the induced velocity field and the rotational inflow. An additional difficulty is encountered as downstream blade elements, which would be present in a multi-component propulsor, pass through the singularity wake sheets shed by upstream components. For these reasons, the propeller blade design code should be coupled with an external flow solver which is capable of transporting vorticity.

Previous researchers have coupled propeller blade design codes with Reynolds Averaged Navier Stokes (RANS) flow solvers. This powerful method made possible multi-element propulsor design in the presence of rotational inflow. Unfortunately, the use of a RANS code is costly in terms of time and computational resources.

This thesis focuses on coupling a propeller blade design code with an axisymmetric, multi-element through-flow code, developed by Drela. The throughflow code uses an integral boundary layer method to solve for the boundary layer flow, and a streamline curvature formulation to solve for the inviscid, outer flow. The main advantage of the present method over previous methods is an order of magnitude reduction in computation time. Validation cases were performed to validate the various components of the coupling procedure, as well as the coupling methodology as a whole. A design case is presented which shows the use of this methodology in design.

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